*A DYNAMICAL HYPOTHESIS OF INHERITANCE.** †

THE doctrine of the preformation of an organism in the germ is as inconsistent with the fact as with the requirements of dynamical theory. The effects of the preconceptions of preformationism have been only too apparent in framing hypotheses of inheritance. The now dominant hypothesis is simply an amplification, in the light of numerous modern facts, of the preformationism of Democritus. He supposed that almost infinitesimally small and very numerous bodies were brought together in the germ from all parts of the body of the parent. These minute representative corpuscles were supposed to have power to grow, or germinate, at the right time, and in the right order, into the forms of the parts and organs of the new being. In this way it was supposed that the characteristics of the parent were represented in a latent form in the germ, which might grow as a whole, by the simultaneous and successive development of the germinal aggregate composed, so to speak, of excessively minute buds, or rudiments of the organs. In such wise also did the successors of Democritus, namely, Aristotle, Buffon, and Erasmus Darwin, suppose that the inheritance of parental likeness by offspring was to be explained. The later and greater Darwin greatly amplified this hypothesis and proposed, provisionally, to account for the phenomena of inheritance by its help. Conceiving the process somewhat as above supposed, he consistently gave to his provisional hypothesis the name of *pangenesis*, since the minute latent buds of the germ were supposed to come from, and thus represent potentially every part of the bodies of the parents, and possibly of still remoter ancestry.

With the discovery of the presence of germinal substance in multicellular organisms, from the embryonic stages onwards, by Owen, Galton, Jäger, Nussbaum and others, the theory of continuity of germinal matter came into vogue. Upon this basis Weismann distinguished two kinds of plasma in multicellular beings, namely, the germ-plasm and the body-plasm, and at first assumed that because of this separation the latter could not modify the former, since the fate of the respective sorts of plasma was predetermined by virtue of this separation. The one kind was the mere carrier of the other, and the germ-plasm was immortal because it was produced in each species from a store of it which always existed, either in a latent or palpable form, from the very beginning of development. He seems, however, in recent years, to have admitted that this germ-plasm could be indirectly modified in constitution through the influence of the body-plasm that bore and enclosed it. Beyond this point Weismann again becomes a preformationist, as truly as Democritus, in that he now conjectures that the supposed innumerable latent buds of the germ, representative of the organs of the future being, are minute masses which he sees as objective realities in the chromosomes of the nuclei of the sex-cells. These chromosomes of the germ he calls 'ids' and 'idants,' according to their condition of sub-division, and supposes them to grow and become divided into 'determinants' and 'biophors' in the course of embryonic development. To these he ascribes powers little short of miraculous, in that he asserts that these infinitesimal germinal particles grow and divide just at the right time and order, and control de-

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† It is interesting to note that the views developed in this lecture lead to conclusions in some respects similar to those held by Professor Whitman in his discourse entitled: 'The Insufficiency of the Cell-Theory of Development,' published in the series of lectures delivered in 1893.

velopment so as to build up anew the arrangement of parts seen in the parent type. This elaborate system of preformationism is bound to produce a reaction that is already becoming apparent; in fact, it is probable that its very complexity, its many inconsistencies, as well as the numerous subsidiary hypotheses that must be worked out to support it, will be fatal to it as a system.

The path along which the solution of the problem of heredity is to be effected lies in a wholly different direction, namely, in that of the study of the mechanics and dynamics of development, and in the resolute refusal to acknowledge the existence of anything in the nature of preformed organs or of infinitesimal gemmules of any kind whatsoever. Such devices are unnecessary and a hindrance to real progress in the solution of the questions of inheritance. They only serve to divert the attention of the observer from the real phenomena in their totality to a series of subordinate details, as has happened in Weismann's case. All this while he has been watching the results of an epigenetic process, as displayed by an inconceivably complex mechanism in continuous transformation, and out of all of this the most essential thing he has witnessed has been one of the *effects* of the operation of that contrivance in the mere splitting of chromosomes that are his 'ids,' 'idants,' 'biophors,' etc. The potentiality of the part has been mistaken for that of the whole.

We must dismiss from our minds all imaginary corpuscles as bearers of hereditary powers, except the actual chemical metameric or polymeric molecules of living matter, as built up into ultramicroscopic structures, if we wish to frame an hypothesis of heredity that is in accord with the requirements of dynamical theory. The 'discovering' and naming of 'ids,' 'biophors' and 'pangenes' time will show to have been about as profitable as sorting snowflakes with a hot spoon. We must also dismiss the idea that the powers of development are concentrated in some particular part of the germ-cell, nor can we assume the latter to be homogenous.* This we are compelled to deny on the ground of the organization of the egg itself. Nor is it possible to deny the reciprocal effects of cells upon each other; the parts are reciprocals of the whole, as the latter is reciprocal to a part. The organism during every phase of its existence is a molecular mechanism of inconceivable complexity, the sole motive force of which is the energy that may be set free by the coördinated transformation of some of its molecules by metabolism. An appeal to anything beyond this and the successive configurations of the molecular system of the germ, as a whole, resulting from the changing dynamical properties of its molecules, as their individual configurations and arrangement change, must end in disappointment. We must either accept such a conclusion or deny that the principle of the conservation of force holds in respect to the behavior of the ultimate molecular constituents of living substance. But to deny that that principle is operative in living creatures is to question direct experimental evidence to the contrary, since Rübner has been able to actually use an organism as a fairly accurate calorimeter.

The initial configuration or mechanical arrangement and successive rearrangements of the molecules of a germ, the addition of

*The writer finds himself unable to agree with Haacke, if he has properly understood that author's assumption as to the homogeneity or monotonous character of living matter, as set forth in his admirable work *Gestaltung und Vererbung*, 1893. Nor does it appear that anything is gained by the acceptance of Haacke's theory of Gemmaria that is not easily understood upon the far simpler grounds that will be set forth here, though there is much in the book cited with which epigenesists must agree, aside from the weighty character of its criticisms and its pregnant suggestiveness.

new ones by means of growth, plus their chemical and formal transformation as an architecturally self-adjusted aggregate, by means of metabolism, is all that is required in an hypothesis of inheritance. The other properties of living matter, such as its viscosity, free and interfacial surface-tension, osmotic properties, its limit of saturation with water, its segmentation into cells, in short, its organization, must be the result of the operation of forces liberated by its own substance during its growth by means of metabolism. We cannot exclude external forces and influences, such as chemism, light, heat, electricity, gravity, adhesion, exosmosis, food, water, air, motion, etc., in the operation of such a complex mechanism. It is these agencies that are the operators of the living mechanism, which in its turn makes certain successive responses in a way that is determined within limits by its own antecedent physical structure and consequent dynamical properties. The parts of the whole apparatus are kept in a condition of continuous 'moving equilibrium' by external agencies, to borrow a phrase of Mr. Spencer's.

This view, it will be seen, leads to a determinism as absolute as that of the Neo-Darwinists, but upon a wholly different basis. It leads to the denial of the direct mutability of the germ by any means other than the transformation, chemical and structural, through metabolism of the germinal mechanism. It not only compels us to deny that the germ can be at once so effected by external blows as to transmit changes thus produced hereditarily except under exceptional conditions, as we shall see later. It denies also, by implication, that the cytoplasm can be so modified, except indirectly, or through architectural transformations of its ultramicroscopic structure.

It is also compelled to deny that spontaneous or autogenous characters can either arise or be transmitted without involving the principle of the conservation or correlation of force, since no transformation of such a mechanism can take place without involving forces directly or indirectly exerted by the external world. In short, the energy displayed by a living molecular system from within must be affected by energies coming upon it from without. All characters whatsoever were so acquired, so that the truth is that there are no others to be considered. Characters acquired through the interaction of inner and outer forces are the only ones possible of acquirement.

That through reciprocal integration (fertilization and formation of an oösperm) this rule may have apparent exceptions, through the compounding of two molecular mechanisms of different strengths, dynamically considered, it is impossible to deny in the face of the evidence of breeders. Such exceptions are apparent, however, and not real, as must follow from dynamical theory.

The sorting process, called natural selection, is itself dynamic, and simply expresses the fact that, by an actual operation with a living body of a certain kind, something more than a balancing of forces is involved between internal and external energies whenever a survival occurs. The principles of dynamics therefore apply in all strictness to natural selection.

What it is that makes crosses or hybrids more variable and often more vigorous than inbred forms must also have a dynamic explanation, since there can be no increased activity of metabolic processes without an increased expenditure of energy and an increased rate of molecular transformation.

Variations cannot be spontaneous, as Darwin himself was aware. The only way in which they can be supposed to have arisen is by the blending of molecular dynamical systems of differing initial potential strengths, by the conjugation of sex-cells (reciprocal integration), and by means of variations in the interactions of such result-

ant systems with their surroundings. This, however, Weismann and his followers deny, though no proof whatever has been offered that such is not the fact. Indeed, it is probable that, so long as the ultimate machinery of metabolism is beyond the reach of ocular demonstration, there can be no proof or disproof of the position assumed by the performationists or Neo-Darwinists. Such proof or disproof is, however, non-essential, since we are forbidden by the first principles of dynamics to assume that transformation of any living physical system whatever can occur without involving some forces or influences that emanate from the external world.* The separation and evaluation of the internal and external forces incident to the manifestation of life, in the present state of our knowledge, and from the very nature of the case, plainly transcends the capacity of present available experimental methods in biology. The discussion as to whether 'acquired characters' are inherited can, therefore, have but one outcome, since external forces can never be excluded in considering the life-history of any organism.

Nägeli, in seeking to account for the phenomena of growth, gave us a most ingenious physical hypothesis of the constitution of living matter. This, later on, he modified so as to develop an hypothesis of hereditary transmission. But the micellæ that were representative of the germinal matter of a species he isolated in the form of rows or chains of micellæ traversing the rest of the living substance of the organism, and called it *idioplasm*. Here again the germinal matter was conceived as separate from that forming the rest of the body. Mr. Spencer supposed "that sperm-cells and germ-cells are essentially nothing more than vehicles in which are contained small groups of the physiological units in a fit state for obeying their proclivity towards the structural arrangement of the species they belong to." These 'physiological units' are neither chemical nor morphological in character, according to Mr. Spencer's system, but it is admitted that their properties and powers must be determined in some way by their own constitution, conditions of aggregation, and relation to the outer world. The views of Nägeli and Spencer are akin in certain respects, but they still retain a certain amount of resemblance to the older ones, namely, those hypotheses which assume that the forces of inheritance are lodged in certain very small corpuscles forming part only of the germ or organism. These hypotheses are also dynamical in nature, and have been worked out with the consciousness, in both cases, that the mechanism of inheritance must also be the one through which metabolism operates. Indeed, these two authors seem to be the first to have distinctly recognized the necessity for such a supposition.

Later still, with the advent of the discovery that the male nucleus was fused with the female nucleus during sexual reproduction, it was assumed that the nuclear contents were the only essential material bearers of those hereditary forces that shape the growing germ into the likeness of the parentage. With the development of this idea the name of Weismann is perhaps most closely associated. He has utilized the facts of development, nuclear cleavage, expulsion of polar bodies, halving and subdivision of chromosomes, etc., as the founda-

*"Some of the exponents of this [preformation] theory of heredity have attempted to elude the difficulty of placing a whole world of wonders within a body so small and so devoid of structure as a germ, by using the phrase structureless germs (F. Galton, Blood-relationship, *Proc. Roy. Soc.*, 1872). Now one material system can differ from another only in the configuration and motion which it has at a given instant. To explain differences of function and development of a germ without assuming differences of structure is, therefore, to admit that the properties of a germ are not those of a purely material system."—JAMES CLERK-MAXWELL, article Atom, *Encycl. Britan.*, 9th ed., Vol. III., p. 42, 1878.

tion of his hypothesis of inheritance. Its extreme elaboration is its greatest weakness, and in it, no less than in all preceding hypotheses, the theory of a separate category of particles carrying hereditary potentialities again appears.

The one criticism that holds of all these hypotheses is that they are one-sided and ignore a most important set of factors in inheritance, namely, the purely statical ones, or those arising from the mere physical properties of the living matter of the germ viewed as if it were a dead, inert mass, subject to the operation of the reciprocal attraction for one another of its constituent particles. All of these hypotheses, moreover, assume that it is only *some* of the matter of the germ that is concerned in the process of hereditary transmission, and that the remainder may be regarded as passive. The entire germ, on the contrary, or all of it that undergoes development, must be considered as a single whole, made up of a vast number of molecules built up into a mechanism. Such a molecular mechanism, it must be supposed, cannot set free the potential energy of its parts except in a certain determinate order and way, within certain limits, in virtue of the initial physical structure of the whole. If the germ is free to do that, as must happen under proper conditions, as a mechanism, its parts, as they are thus formed by their own metabolism, it may be assumed, will inevitably and nearly recapitulate the ancestral development or that typical of the species. It must do this as a mere dynamical system or mechanism, the condition of which at one phase determines that of the next, and so on, to the completion of development.

In the present state of our knowledge we are not prepared to frame a purely mechanical hypothesis of inheritance that shall answer every requirement, in spite of the fact that no other is possible. Herbert Spencer and Professor Haeckel long ago pointed out that such an hypothesis is a necessity growing out of the very requirements that must be satisfied in any attempt to coördinate the phenomena of biology with those of the not-living world. The material basis of life is always a chemically and mechanically compounded substance. To the very last molecule, such a body must betray evidence of arrangement or structure of its parts that should make it a mechanism of the utmost complexity and requisite potentiality as a transformer of energy through the mere transposition and rearrangement of such parts. We find indeed that living matter is chemically the most complex and unstable substance known. It is composed largely of carbon, a quadrivalent element that stands alone in its power to combine with itself and at the same time hold in chemical bondage groups of atoms representing other chemical bodies. Such groups are probably held together in great numbers metamerically by the reciprocal or otherwise unsatisfied affinities of the large number of carbon atoms entering into the composition of the proteid molecule. In this way the massive and structurally complex molecule of protoplasm may be supposed to have arisen. We may thus trace the genesis of the peculiarities of living matter to this singular property of the carbon atom. On such a basis we may suppose that the ultimate molecular units are identical with the physiological units, so that their structures may not only determine the nature of the metabolism they can undergo, but also be the ultimate units of form or morphological character.

What especially gives color to these suspicions is the extraordinary variety of changes, alteration of properties or powers, and the vast variety of living matter, as represented by the million or more of known distinct living species of organisms. It is as if the permutations, transformations, and the dynamical readjustment of the meta-

meres of the molecules of living matter were the source of its varying potentialities as manifested in its protean changes of specific form and function. That some mechanical and consequently dynamical interpretation of these transformations may yet be forthcoming is, I take it, distinctly foreshadowed by the advances in the newer theories of stereo-chemistry developed by LeBel and Van't Hoff. If this is the case we may yet hope for a mechanical and dynamical explanation of the phenomena of life and inheritance. Especially is this true if we further suppose that the large molecules of living plasma are rather feebly held together by a force almost of the nature of cohesion. We may be permitted thus to find an explanation of that phenomenon which is always so characteristic of living matter, namely, the large and relatively fixed amount of water it contains, and also the mobility of its molecules in respect to one another, its jelly-like character at one instant, its fluidity and power of motion at another. It is indeed probable that the amount of water contained in living matter is controlled within certain limits by the forces of cohesion exerted between adjacent molecules against the osmotic pressure or capillary action of water tending to drive them asunder, as supposed by Nägeli, in his hypothesis of micellæ. Such an hypothesis enables us to explain much that is otherwise quite unintelligible in relation to living things. It renders us an explanation of amœboid motion, of the surface tensions of protoplasm and lastly of metabolism itself through osmosis and the specific characters of the chemical transformations that must take place in each kind of living substance.

Such an hypothesis may also afford us mechanical constructions of atoms, grouped into very large metameric or polymeric molecules of the utmost diversity of powers, capable of undergoing a long series of successive transformations, so as to manifest in the long run, starting with a molecular germinal aggregate, what we call ontogeny or development. These transformations, we must suppose, are effected by the metabolism incident to growth, and moreover, that starting with an initial configuration of a system of molecules, as a mechanical and consequently a dynamical system of determinate powers, in the form of a germ, it cannot undergo any other transformations except such as lead to an approximate recapitulation of the ancestral development or phylogeny. This supposition follows from the rule that must hold of determinate systems of molecules, as well as of systems formed of larger masses, namely, that the initial changes in the configuration of such a complex system must dynamically determine within certain variable limits, under changing conditions, the nature of all of its subsequent transformations, including those due to growth and consequently increased complexity. We thus escape the necessity of invoking certain 'proclivities' of physiological units, or the necessity of appealing to the growth and fission of 'biophors' or the scattering of 'determinants' at the proper times and places in the course of development. We thus escape, too, the mistake of assuming that a part of a germ controls the whole, a proposition that has been so long advocated by one school of biologists that it is astounding that its fallacy has not long since been more generally understood. Such a doctrine is not credible in the face of the fact that we know of no development except that which takes place in intimate association with cytoplasm, which seems to be the principal theater of metabolism and growth. We cannot conceive of the transformations of a germ without considering the metabolism of all its parts, such as nucleus, cytoplasm, centrosomes, archoplasm, chromatin, spindles, astral figures, microsomata, etc.

'Tendencies' and 'proclivities' are words that have no legitimate place in the discussion of the data of biology any more than they have in natural philosophy or physics. Karyokinesis, now admittedly inseparable in thought from the idea of multicellular development, is a rhythmical process so complex in its dynamical aspects as to some extent lead one unwittingly to underestimate the absolute continuity of the accompanying processes of metabolism. But that is no reason why the importance of nuclear metamorphosis should be exaggerated at the expense of the far more important forces developed by metabolism and growth. In fact, the 'ids,' 'idants,' etc., of that school of biologists are not causes but mere effects, produced as passing shadows, so to speak, in the operation of the perfectly continuous processes of metabolism incident to development. Reciprocal relations are sustained between nucleus and cytoplasm of such importance that the transformation or fission of the one is impossible without the other.

The so-called 'reducing divisions' probably have nothing but a passing and purely adaptive physiological significance in every ontogeny of ova and sperms. The far-fetched and extraordinary teleological significance given by some to the reducing divisions would lead one to suppose that the clairvoyant wisdom of the original egg that thus first threw out the excess of its ancestral 'germ-plasm' in order to save its posterity from harm through the fatality of reversion thus entailed was greater than anything human, if not god-like. The complete parallelism of the 'reducing division' in the sperm and egg has never been established. The comparison of these processes in the two is still only approximate, because in the truly holoblastic egg there is, in some cases, an apparent temporary substitution of the male nucleus for the female, as is shown by the former's assuming a position of equilibrium at the center of the ovum (*Ascaris*), a condition of things that does not and could not occur in the sperm cell.

A still more important contrast is the almost incredible difference of volume of the two kinds of sex-cells of the same species. In man the ratio of volume of the male cell to the female cell is as 1 to 3,000 approximately. This extreme contrast of volume is associated with corresponding contrasts in their properties. There can hardly be any doubt that the mature male cell is in a nearly potential or static state of metabolic transformation of its substance, and is characterized by an almost complete want of stored metabolizable reserve material. The egg is in a similar static state, but, on the other hand, contrasts with the male element in that the development of a more or less voluminous mass of reserve material within it has seemingly been also associated with its loss, as a rule, of the power to begin an independent development. The power of the male cell to begin its transformation and growth through metabolism appears to be arrested until it finds the material in which its mere presence will set up transformations. This it must do by in some way setting free and diffusing some of its own molecules osmotically and mechanically through the egg. The substance of the egg appears therefore to be complementary to that of the spermatozoön. The power to set up transformations within the egg leading to the development of a new being is not manifested aside from the presence of the male element except in cases of parthenogenesis. Even the expulsion of the polar cells is not initiated until the stimulus of the presence of the male element is experienced by the egg.

Another contrast is found in the times of the advent of the 'reducing division' in the two kinds of sex-cells. In the male cell the 'reducing division' occurs earliest, or while it is still in more or less close nutri-

tive relation to the parent; in the egg the 'reducing division' or expulsion of polar cells does not occur till the egg is freed, as a rule, from the parent gonad, and generally as a consequence of the stimulating effect of the presence of the male cell. These differences of behavior of the two sorts of sex-cells seem to be correlated with their differences in size.

We may contemplate the sex-cells as molecular mechanisms which, in virtue of their mechanical structure, are rendered capable of controlling the order and manner of rearrangement of their constituent molecules, because of the new successive attractions and repulsions set free, amongst the latter, immediately upon the completion of conjugation. The new forms of metabolism thus initiated enable us to conceive a mechanical theory of fertilization. At any rate, the two sorts of sex-cells are potentially the reciprocals of each other, and their initial or *statical* states cannot begin to set free their energy and thus pass into the successive kinetic states of formal change until the two mechanisms are reciprocally and mechanically integrated into a single one by means of conjugation. The parts of this new single body now act in unison. Even the manner in which the two conjoined molecular mechanisms operate can actually be to some extent traced, as expressed in the complex movements associated with fertilization, the division of the chromosomes and centrosomes. The effect of conjugation is to afford opportunity also for new and various combinations of molecular mechanisms, though the reciprocal integration of pairs of cells having a widely different parentage.

The great size of the egg-cell provides an extensive reserve material that enables the embryo thus built up usually to reach a relatively great size without entering for a time into competition for food in the struggle for existence. Sexuality is therefore altruistic in nature, since it has led in both plants and animals to the evolution of a condition of endowment, or the storage of potential energy in the germ, so that the latter is the better able to cope with natural conditions. While it may be assumed that sexuality has arisen, in the main, under conditions determined by natural selection, once sexuality was attained, the added power thus accumulated potentially in large germs of double origin enabled the latter the more easily to overcome untoward natural conditions. Natural selection thus becomes altruistic or dotational in that it tends through sexuality to defeat the deadliness of the struggle for existence, just as we may also assert that the theory of superposition to which the mechanical theory of development is committed is also finally altruistic. It may be remarked that the greatest mortality of a species, under the conditions of the struggle for existence, also takes place in the egg and embryonic stages, or before organisms can experience acute pain; so that here again we have a result that must materially ameliorate the pains and penalties of the struggle for life.

These details are, however, of minor import for us just now. The important thing to bear in mind is that all of the forces of development are ultimately metabolic in origin, and that the wonderful order and sequence of events in any given ontogeny arise from the transformation or transposition of the parts of a molecular system that also thus increases in bulk by the addition of new matter. The steps of this transformation are mechanically conditioned by dynamical laws with as much unerring certainty of sequence as those that control the motions of the heavenly bodies. The consequence of such a view is that we can thus free our minds of all traces of belief in a theory of preformation. The embryo is not and cannot be preformed in the germ, as

observation and physiological tests prove; nor is such preformation necessary if a mechanical hypothesis is adopted.

JOHN A. RYDER.

(*To be concluded.*)

CURRENT NOTES ON PHYSIOGRAPHY (VIII.)

CROWLEY'S RIDGE.

CROWLEY'S RIDGE, rising above the alluvial lowland of the Mississippi in Missouri and Arkansas, has long been a subject of discussion. Branner (Geol. Surv. Ark., Ann. Rep., 1889, ii., p. xiv.) has suggested that the lowland to the west of the ridge was excavated as an early path of the Mississippi, from which it was diverted into its present course east of the ridge by the Ohio; but it is difficult to understand how the smaller of the two rivers could divert the larger one. A new explanation of the ridge has recently been offered by C. F. Marbut (Proc. Boston Soc. Nat. Hist. xxvi., 1895), to the effect that the ridge is homologous with the Chunnenugga ridge of Alabama, and that it belongs to a family of geographical forms frequently found on coastal plains during the mature stages of their development. These ridges or uplands normally run parallel to the coast line; they mark the outcrops of comparatively resistant strata, dipping toward the coast; they descend inland by a relatively rapid slope, often strong enough to be called an escarpment, towards an inner lowland which has been eroded on an underlying and weaker member of the coastal formations; they descend more gently on the coastal side. The inner lowland is drained by longitudinal streams, which enter transverse streams that cut their way through the ridge or upland on the way to the sea. In a region of uniform uplift all these features of relief and drainage have a regular rectangular system of trends; but where the former shore line or the uplift is irregular the trends will depart more or less from a rectangular towards a curved pattern. Marbut regards Crowley's ridge as a portion of an inland-curving ridge of this kind. The master stream of the region is the Mississippi, which bisects the inland curvature of the ridge. The upland along whose eastern base the Tennessee river flows northward in an adjusted subsequent course forms the eastern part of the curve; while Crowley's ridge forms the western part. The lignitic strata by which the ridge is determined weaken southwestward, and hence the ridge soon disappears in that direction. The lowland west of Crowley's ridge, ascribed by other writers to erosion by the Mississippi, is explained by Marbut as comparable to the lowland on the inland side of the Chunnenugga ridge of Alabama, and the rivers which follow this lowland are thought to be adjusted subsequent rivers.

THE CUSPATE CAPES OF THE CAROLINA COAST.

THE systematic repetition of certain features in Capes Hatteras, Lookout and Fear is explained by C. Abbe, Jr. (Proc. Boston Soc. Nat. Hist., xxvi., 1895) as the result of a number of backset eddying currents, turning from right to left between the Gulf Stream and the coast. The generally southward movment of the sands along the shore being well known, some special explanation is needed for the acutely pointed capes between the smooth concave curves of the sand bars. Although this is a conspicuous feature of the coast, it seems to have been little considered. Shaler, in his recent general account of Harbors (U. S. Geol. Survey, 13th Ann. Rept., 1893, 180), suggests that the greater inflow of the tides in the middle of the curved bays between the capes would cause a lateral current in either direction, and that the cusps would form where the outward flow from two curves became confluent; but this is contradicted not only by the general southward movement of sands along the shore, but also